Justification of impregnation modes for wood

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Abstract. One of the most significant disadvantages of wood materials is increased combustibility. Therefore, the problem of reducing the combustibility of wood materials is relevant. The article describes an experimental study of impregnation of wood using biopiren MIG-09, which is a hybrid composition on a salt basis with the addition of functional substances of non-salt nature, at different temperature regimes. Two stages of the study were chosen for the experiment. The optimum temperature regimes for different methods of applying the composition to increase the fire resistance of wood were established experimentally. Also fire tests were carried out to analyze the degree of penetration of the solution.

1. Introduction

The use of traditional methods of fire protection of wooden structures is due to the availability of the used compositions, the ability to provide almost any fire resistance limit, as well as a relatively low cost [1]. The disadvantage of these methods is the shallow penetration of flame retardant and, therefore, low consumption rates of compositions [2-4].

Impregnation is one of the effective methods of applying protective agents. It is believed that the deeper the wood is impregnated with a fire retardant composition, the more reliably it is protected. This is the method by which the fire retardant solution penetrates most deeply into the wood and works best [5-7].

The mechanism of fixing in wood "MIG-09" is a hybrid composition, on a salt basis with addition of functional substances of non-salt nature.

The most promising areas of research are: reducing the number of components in the compositions, reducing the density of the coating, using industrial wastes as components, improving such performance characteristics as water resistance, adhesion [8-12].

2. Materials and methods

To study the impregnation of wood samples the MIG-09 flame retardant composition was used, at different temperature regimes (see table 1).

Samples for testing the fire resistance of impregnation composition are made in accordance with State Standard 2140, State Standard R 53292-2009.

The direction of arrangement of fibers in the wood slice along the fiber can be determined by figure 1. In order to minimize the effect of machining on the fire retardant efficiency of the samples surfaces of the working part were made smooth, without cracks and other defects [11].

Table 1. Impregnation modes.

	Modes					
Characteristics of the composition(ºC)	1 46 ºC	2 41 ºC	3 36 ºC	4 31 ºC	5 26 ºC	6 26 º C impregnation in two stages
Appearance	Translucent, grayish-yellow liquid					
Dilution factor by mass, (kg)	1:5.0 (1 kg concentrate, 5.0 l water)					
Dry concentrate (g)	200					
Volume of prepared solution (g/m^2)	600					
Processing temperature (ºC)	26					

Figure 1. The appearance of the fibers in the section of the sample.

The samples were made in the form of a cube with a cross section of 50x50 mm and a fiber length of 50 mm, with a moisture content of 25% and a density of 400-550 g/m^3.

The experiments were conducted in two stages:

At the first stage, wood samples were soaked in a solution of flame retardant at different temperatures: 46, 41, 36, 31 и 26 ºC, that is, the interval between the compositions was ±5 ºC (figure 2).

At the second stage, in order to deeply impregnate the samples, they were soaked in impregnation compositions twice at temperature ±26 ºC, at intervals of 24 hours.

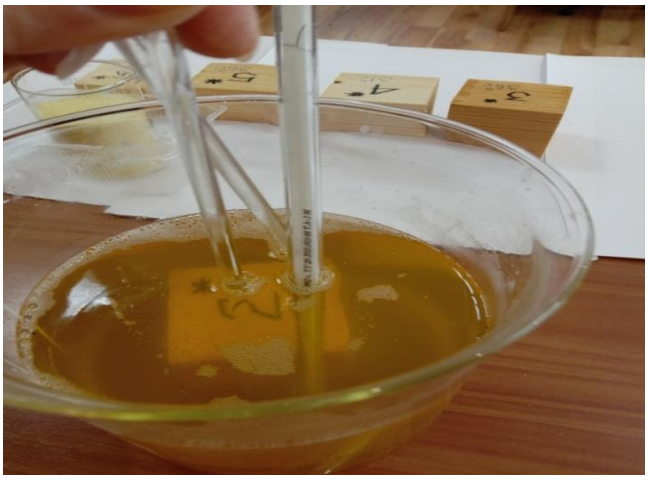

Figure 2. Sample soaking process.

3. The results of the tests

The result of the first phase of research is shown in table 2.

Table 2. Results of the first phase of the experiment.

Sample number	Mass before impregnation(g)	Mass after Impregnation (g)	Time processing	Drying time at temperature (23±5)° C
1[a]	43.135	43.311		
2[a]	46.996	47.901		
3[a]	45.883	46.118		
4[b]	42.729	43.378		
5[b]	35.996	36.952		
6[b]	38.780	39.744		
7[c]	43.797	44.286		
8[c]	36.986	37.770	2 mins.	24 hours
9[c]	37.876	38.239		
10[d]	44.332	44.646		
11[d]	36.992	37.508		
12[d]	35.938	36.697		
13[e]	44.192	44.795		
14[e]	39.017	39.410		
15[e]	38.907	39.255		

[a] wood impregnated at 46° C; [b] wood - at 41° C; [c] wood - at 36° C; [d] wood - at 31° C; [e] wood at - 26° C.

The total impregnation (absorption) rate was determined by measuring the mass of the sample before and after impregnation with fire retardant. The results are shown in table 3.

Table 3. Total absorption of the flame retardant.

Sample number	Mass of the absorbed composition (flame retardant) (g)	Total absorption R, (kg/m^3)
1[a]	0.176	1.408
2[a]	0.905	7.240
3[a]	0.235	1.880
4[b]	0.649	5.192
5[b]	0.956	7.648
6[b]	0.964	7.712
7[c]	0.489	3.912
8[c]	0.784	6.272
9[c]	0.363	2.904
10[d]	0.314	2.512
11[d]	0.516	4.128
12[d]	0.759	6.072
13[e]	0.603	4.824
14[e]	0.393	3.144
15[e]	0.348	2.784

As it can be seen from the results of stage 1 of the experiment, the absorption coefficient was:
- low - 1.408-1.88;
- middle - 2.512-5.192;
- high - 6.072-7.712.

Samples 1 and 3 at temperature 46° C showed a low absorption coefficient, and sample 2 showed a high absorption coefficient. Thus, at temperature 46 °C the desired result is not detected, at a temperature of 41 °C samples 5, 6 have the best absorption coefficient, and sample 4 - the average. At temperatures of 36° C, 31° C, 26 °C all samples have an average absorption coefficient.

At the second stage of the experiment, the samples were impregnated two times each at temperature 26 ºC. The results of the experiment are shown in table 4.

Table 4. Results of the second phase of the experiment.

Sample number	Mass before impregnation (g)	Mass after impregnation (g)	Time Processing	Drying time at temperature (23±5)º C
1	42.915	43.556		
2	36.962	37.551		
3	44.350	44.471		
4	43.046	43.975		
5	39.996	40.320		
6	37.033	37.845		
7	44.590	44.736		
8	48.034	48.703	2 mins.	24 hours
9	37.840	38.288		
10	43.480	45.510		
11	48.250	49.864		
12	43.036	44.034		
13	49.819	51.288		
14	46.250	47.604		
15	47.937	49.729		

The total absorption of the flame retardant for the second stage of the experiment is shown in table 5.

Table 5. Total absorption of the flame retardant.

Sample number	Mass of the absorbed composition (flame retardant) (g)	Total absorption R, (kg/m^3)
1	0.641	4.912
2	0.589	4.7.12
3	0.121	9.68
4	0.929	7.432
5	0.324	2.592
6	0.812	6.496
7	0.146	1.168
8	0.669	5.352
9	0.448	3.584
10	2.030	16.240
11	1.614	12.912
12	0.998	7.984
13	1.469	11.752
14	1.354	10.832
15	1.792	14.336

In the second stage of the experiment, the impregnation composition was applied to the samples in two layers at a temperature of 26 ºC. As the experiment showed, nine out of fifteen samples have the highest absorption coefficient (table 5), and four samples - the average, which provides the first category of fire protection efficiency.

For clarity of the conducted experiments a diagram was built (figure 3). The results show that when impregnating in one layer, it is most effective to maintain the temperature regime around 41º C. When impregnating in 2 layers, an increase in temperature has a negative effect on absorption, therefore, it is necessary to carry out the impregnation process at a temperature closer to room temperature (26 ºC).

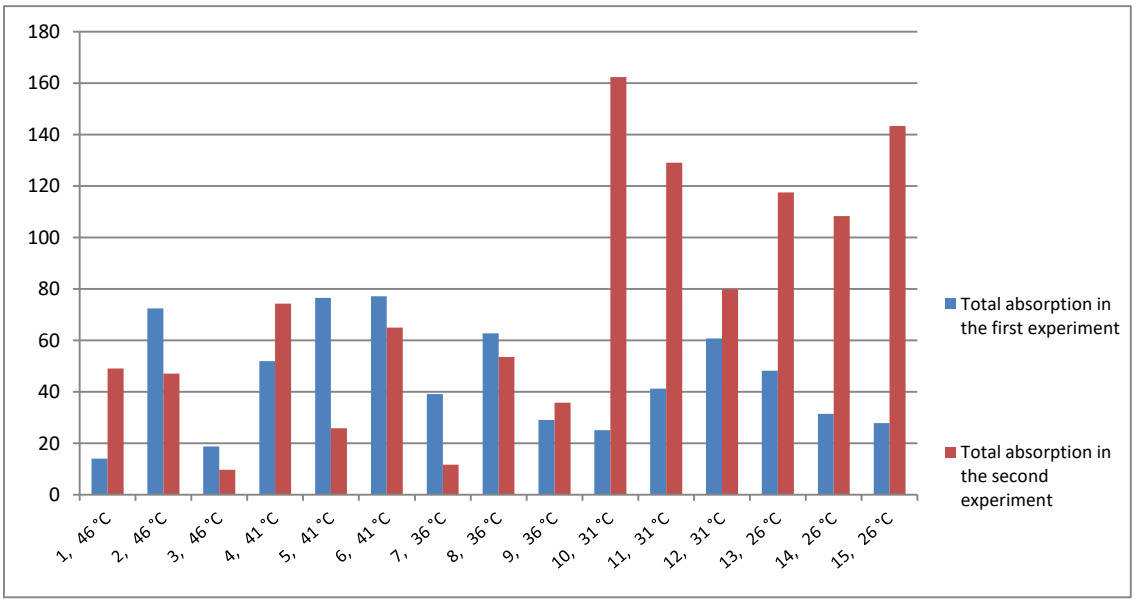

Figure 3. Effect of impregnation temperature regime on the total amount of absorption of samples.

At high temperature impregnation, the absorption of the composition into the wood is deeper, which increases the smoldering of wood and does not lead to rapid burning of wood material. At the same time there is an increase in the fire protection group: one-stage impregnation up to the II group of fire protection efficiency, two-stage - up to the I group of fire protection efficiency.

The depth of penetration of the composition was assessed in accordance with State Standard 27014-86.

Upon completion of impregnation, wood samples were split along the fibers in two directions perpendicular to each other and to the sides (figure 4). The samples were 20 mm thick, 50 mm wide, and 50 mm long. The depth of penetration of the protective agent (impregnation solution) was determined on the split surfaces).

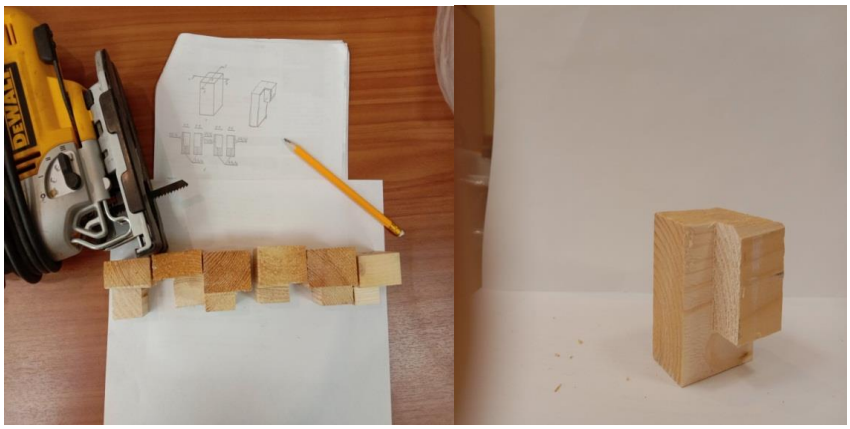

Figure 4. Sawing wood samples and measuring the impregnation depth.

Also to analyze the degree of penetration of the impregnating composition, fire tests were carried out. Preliminary test specimens were placed in an experimental cabinet (consisting of a ceramic box with outer dimensions of 120x120x300 mm and wall thickness of (16±2) mm), with a metal holder).

The results of studies of fire properties revealed that the use of flame retardant MIG-9 to improve the fire resistance of wooden structures also allows to improving its class of structural fire hazard to class K1, and hazard class of the materials on which it is applied to class KM2.

4. Conclusion

When impregnating in one layer the best temperature regime of impregnation with flame retardant MIG-9 is 41 ºC. And when impregnating in 2 layers it is necessary to carry out the process at a temperature closer to room temperature (26 ºC).

When treating wood with fire retardant composition at high temperature you can achieve deep absorption of the composition into the wood regardless of the wood species, the drier the wood, the deeper is the penetration and caking of wood pores, which does not allow the oxidant (oxygen) to penetrate the wood, and thus preventing the process of burning. If the product is impregnated in several layers, the protective layer increases not due to adhesion, but due to absorption and creation of an integral protective "wall" and the quality of the product does not change.

It has been shown that an increase in fire protection group is achieved: in one-stage impregnation up to Fire Protection Group II, in two-stage impregnation up to Fire Protection Group I.

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